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# EQUIPMENT AND TECHNOLOGY

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# FINE-MILLING AND AIR CLASSIFICATION OF CERAMIC MATERIALS BY THE DRY METHOD

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In this article, modern methods of fine milling and air classification of materials by the dry method, making possible precise sizing of particles as well as clean processing of the initial product without foreign impurities, are presented. Special wear-resistant construction of the working units permits the finest milling and classification of even the hardest materials, including those with a hardness of up to 10 on the Mohs scale.

***Key words:*** fine milling, air classification, jet mill, high-efficiency classifier, air medium, milling technology using superheated steam, fine classification of micropowders.

In the ceramic industry mechanical processing of raw, auxiliary, or finished materials is an important part of many production processes. Milling and classification processes for obtaining a definite particle size distribution are of paramount importance.

The counterflow jet mill with a fluidized bed has established itself to be especially effective for milling ceramic and abrasive materials. Today the jet-milling technology makes it possible to obtain a fine grind down to the submicron range with controllable particle sizing.

## ELEMENTS OF JET MILLING

Counterflow jet mills with a fluidized bed operate according to the principle of decompression of compressed gases and are most suitable for the finest milling of hard materials (up to 10 on the Mohs scale) with negligible wear of the grinding tools.

This milling principle also makes it possible to satisfy special additional requirements, such as maintaining the color tone of the milled material or avoiding foreign impurities.

### Principle of Operation of a Jet Mill

The product to be milled is fed through a double flap valve into a branch pipe *1* (Fig. 1). A fluidized bed of material is formed in the base of the milling chamber *2* by gas streams entering from the milling nozzles *3* located below the branch pipe level. The particles of this "fluidized bed" are drawn into the gas stream and are accelerated with increasing speed towards the center of the chamber. Milling occurs as a result of collisions between the particles in the gas streams formed. As a result of this autogenic method of

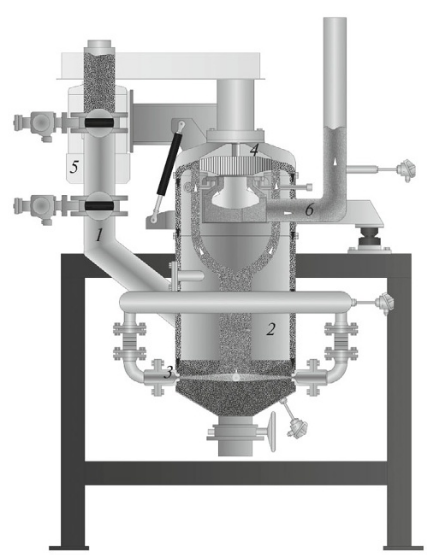


**Fig. 1.**

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milling, contamination of the product with foreign impurities does not occur.

The decompressed milling gas together with the particles rise upwards to the classifying rotor *4*, which is driven by an electric motor through a V-belt *5*; a frequency converter regulates the rotation rate of the rotor. Course particles are rejected from the classifying rotor by centrifugal force and return into the fluidized bed, where they are re-milled. Fine particles together with the milling gas stream enter the classifying rotor and leave the mill through the fines outlet *6*. Finally, the fine fraction of the product is separated from the working gas in a cyclone or filter system.

The patented design of the ConVor® classifying rotor (Fig. 2) makes extremely fine classification of the products possible. The constant radial velocity of the gas in the rotor, co-rotating (exchangeable) immersion tube, and strong construction make it possible to obtain a flexible final particle size in the range $d50 = 70 - 1$ μm. Even though only one classifying rotor is used, the productivity of the mill reaches the highest possible values.

Depending on the product and the initial problem, there are two laboratory machines and seven production units in the model series of jet mills.

A CGS milling plant with a jet mill is shown in Fig. 3. The usual plant consists of feeding equipment, mill, gas-filtering system, and other components. A cyclone can be installed between the mill and the filter hoses to optimize cleaning. This configuration is used for production processes in which the product has to be changed frequently or the product has intense color, for example, ceramic pigments.

## TECHNOLOGIES USED

### Operating Mode with Hot Gas under High Pressure

This operating mode is used in industries in which ceramic materials must be processed. This is because these products are insensitive to temperature and their hardness requires higher adiabatic energy for milling. In such a mode, elevated air temperature is used at the exit from the two-step, oil-free compressor, and compressed air is used for milling without a subsequent cooling stage. Depending on the type of compressor, it is possible to work at milling gas temperatures from 80 to 200°C (maximum) with excess pressure from 6 to 9 bar. The usual applications are milling glass frits, quartz, tungsten carbide and ceramic pigments, as well as oxide, nitride, and carbide ceramics.

**Fig. 2.**

### S-Jet Technology

In recent years the constantly increasing demand for ever finer powders served as an impetus to develop a new technology, opening up extensive possibilities for dry milling of powders in the submicron range. The result of the S-Jet® technology developed by NETZSCH-CONDUX Mahltechnik GmbH is a milling fineness up to $d50 = 0.2$ μm — the finest dry milling in the world.

Compared with the conventional method of dry milling in jet mills, the new S-Jet® technology uses superheated steam as the milling gas instead of compressed air.

When working with superheated steam, the particle flow velocities in the milling chamber increase to 1200 m/sec, which is a factor of approximately 2 higher than in the case of compressed air. The adiabatic milling energy increases (according to the relation $E = 1/2\ mv^2$) by a factor of 4 and

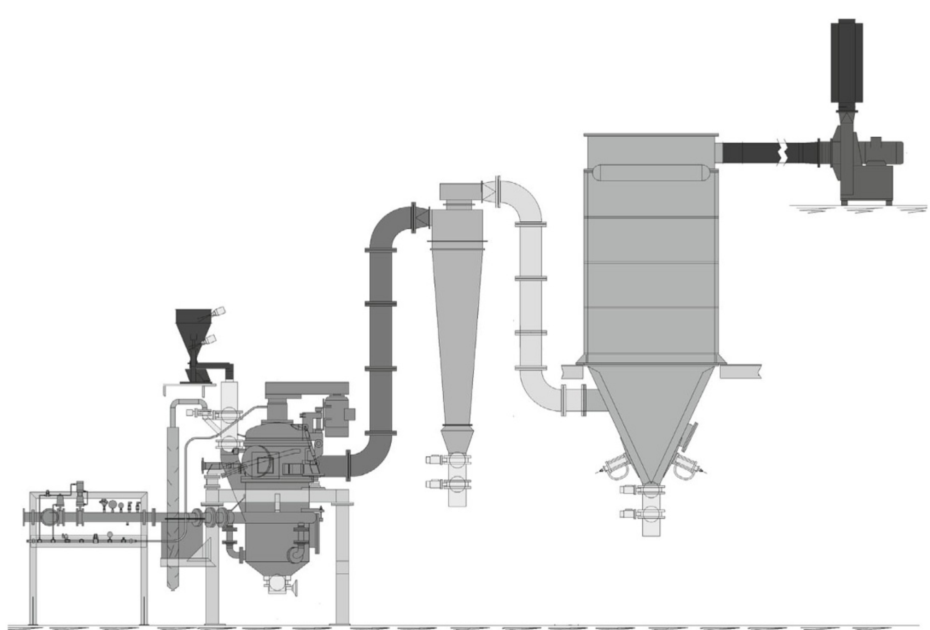

**Fig. 3.**

**TABLE 1.** Milling Parameters in a Jet Mill in Different Media

| Index | Milling medium | | | |
|---|---|---|---|---|
| | Air | | Superheated steam | |
| Milling parameters: | | | | |
| absolute pressure, bar | 4.5 | 11 | 40 | 100 |
| at temperature, °C | 220 | 150 | 320 | 400 |
| Decompression (in the classifier zone): | | | | |
| absolute pressure, bar | 1.1 | | 1.1 | |
| at temperature, °C | 150 | | 150 | |
| Flow velocity at nozzle exit, m/sec | 493 | 652 | 1151 | 1294 |
| Density at decompression, $kg/m^3$ | 0.91 | | 0.57 | |
| Specific power of the flow at decompression, $kW/m^3$ | 0.043 | 0.053 | 0.1 | 0.13 |
| Dynamic viscosity at decompression, Pa · sec | $2.41 \times 10^{-5}$ | | $1.42 \times 10^{-5}$ | |
| Sound speed at decompression, m/sec | 412 | | 504 | |

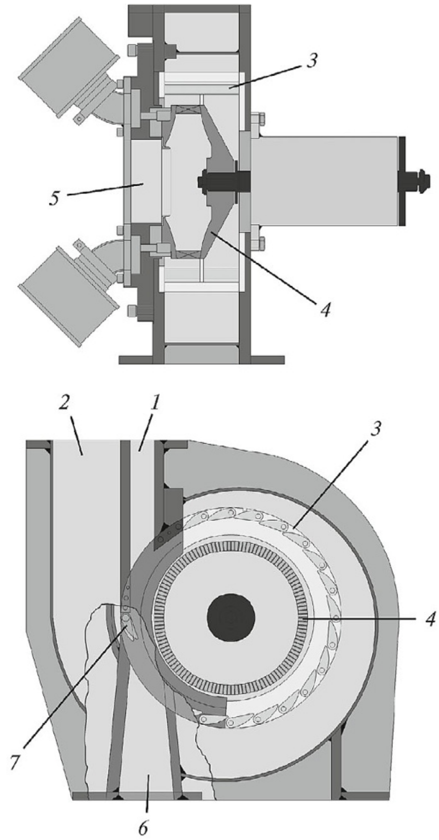


**Fig. 4.**

makes it possible to obtain material with a particle size that previously could only be obtained by wet- milling.

Since superheated steam has a much lower dynamic viscosity and higher sound speed than air, the peripheral speed of the gas stream inside the classifier rotor also increases, and therefore the acceleration of the particles of the material being classified also increases.

As an example, when the peripheral speed increases from 200 to 300 m/sec, the particles undergo centrifugal acceleration by a factor of 2.25. The centrifugal force equals the mass multiplied by the acceleration. This means that the centrifugal force can be increased by the same amount as the centrifugal acceleration. This decisive factor makes it possible to obtain a separation cut in the submicron range in the dry milling process (Table 1).

The new S-Jet® also has interesting economic aspects: depending on the steam pressure, the specific power of the flow increases by approximately a factor of 2.6. For similar particle milling size, the productivity of the mill increases correspondingly by the same factor compared with the operating regime with compressed air. Another advantage of this principle is the possibility of drying the product during the milling process. During a number of recent tests of this mill, suspensions comprised of 70% solid phase were processed. As a result of milling, a fine dry powder was obtained at the output.

To classify milled products, for example, to remove the undesirable fine or coarse fraction, high-efficiency classifiers belonging to the latest generation of the model series CFS/HD-S are used (Fig. 4). The product is fed through a feed pipe at the top of the machine *1*. The working gas enters through the air channel *2*, breaks up agglomerates of the loaded material through numerous guide vanes *2*, and then feeds the material to the classifying rotor *4*. Here, the material is divided into coarse and fine fractions in accordance with the set (evenly regulated) rotation speed of the classifying rotor. The finely dispersed product leaves the machine through the rotor at the center of the machine. The "coarse particles" fly out of the rotor and are discharged through the exit channel of the coarse fraction *6* at the bottom from the backside of the machine housing, which is implemented in a screw form and has a separating wall *5*. This part of the machine effectively prevents mixing of the loaded material with processed material. In complex classification problems the residence time of the material in the chamber is regulated by adjusting the position of the so-called material flap *7*. This makes it possible to influence the "quality of classification" of the coarse product.

In this configuration of the machine a patented ConVor® rotor with a co-rotating immersion tube is also used in order to optimize the yield of the fine fraction. The classifier is designed for the separation range $d97 = 70 – 2$ μm.

A typical plant with a CONDUX high-efficiency ultrafine-separation classifier CFS HD-S type as a complex system is displayed in Fig. 5. The classifying plant consists of a feeding screw for uniform feeding of material, classifier, cy-

clone, and dust-catching hose filter. A rotary piston blower for generating the process gas is mounted after the filter in order to operate in low pressure mode.

This classifier is placed inline immediately after the mill to remove dust or limit the coarse fraction at the preliminary production stage.

Usually, NETZSCH-CONDUX classifiers are used to eliminate the fine fraction from the milled products or separate the coarse fraction after production processes in which there is no sizing of coarse particles, for example, after ball mills. In such cases the mill and classifier operate in a circulation mode.

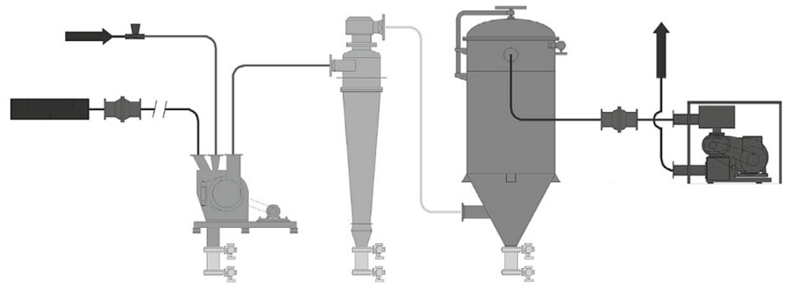

**Fig. 5.**

In NETZSCH-CONDUX Mahltechnik's range of products, there are two laboratory scale machines for research and development purposes and seven production size machines. After purchasing a laboratory machine, the customer can carry out tests in his laboratory. Based on the results, an accurate scale-up calculation can be made in order to select the most suitable production machine for their production application.

### Wear Resistance of the Plants

For milling or classification of solid materials it is necessary to provide protection from wear. Special attention is devoted to the classifying rotor, since it is subjected to high wear because it comes into contact with product moving at high peripheral speeds. For this reason special constructions of the rotor with vanes made of hard metals or ceramic guide vanes were developed. The housing and parts of the plant components, for example, piping and filter cones, are lined with ceramic or polyurethane. On the basis of many years of experience NETZSCH specialists have developed special recipes for wear-resistant materials, which increase the service life to the maximum possible level.

## CONCLUSIONS

In order to make an economically expedient choice of a jet milling or classification concept, taking into account the investment and operating costs, it is necessary to perform tests with the original material from the customer together with a specialist from NETZSCH-CONDUX Mahltechnik GmbH. For these purposes, our customers have the possibility of working together with the State Polytechnic University in St. Petersburg to perform tests on the CGS 10 laboratory jet mill. After the tests are completed, the particle size distribution, shape, and microstructure of the particles, as well as the specific surface area of the powder, are determined in experiments performed using modern analytical equipment.

For tests on a production scale with the customer's material, we propose a grinding plant with the jet mill CGS 71. In this case, the minimum product batch size is 500 kg. These tests can be performed at our partner company — UralMin Company in Chebarkul' (Chelyabinsk Oblast').

We can also perform extensive tests for the development of new individual processes/technologies for milling and classification in our test center in Hanau (Germany). The NETZSCH laboratory is equipped with the latest analytical equipment and various types of mills and classifiers. Please contact us by telephone at +7 (495) 937 85 15 or by e-mail at nft.moskau@netzsch.com.